

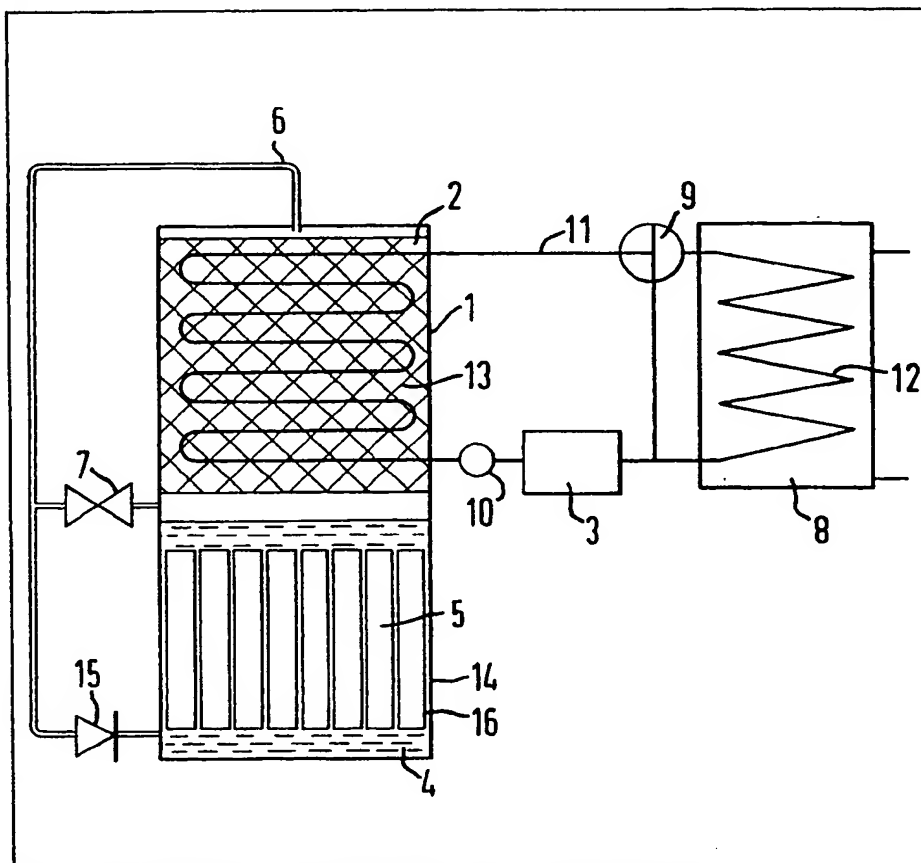
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(54) Heat storage system

(57) A heat storage system comprises a pipe circuit 11 in which a fluid (e.g. silicone oil or water) is circulated by a

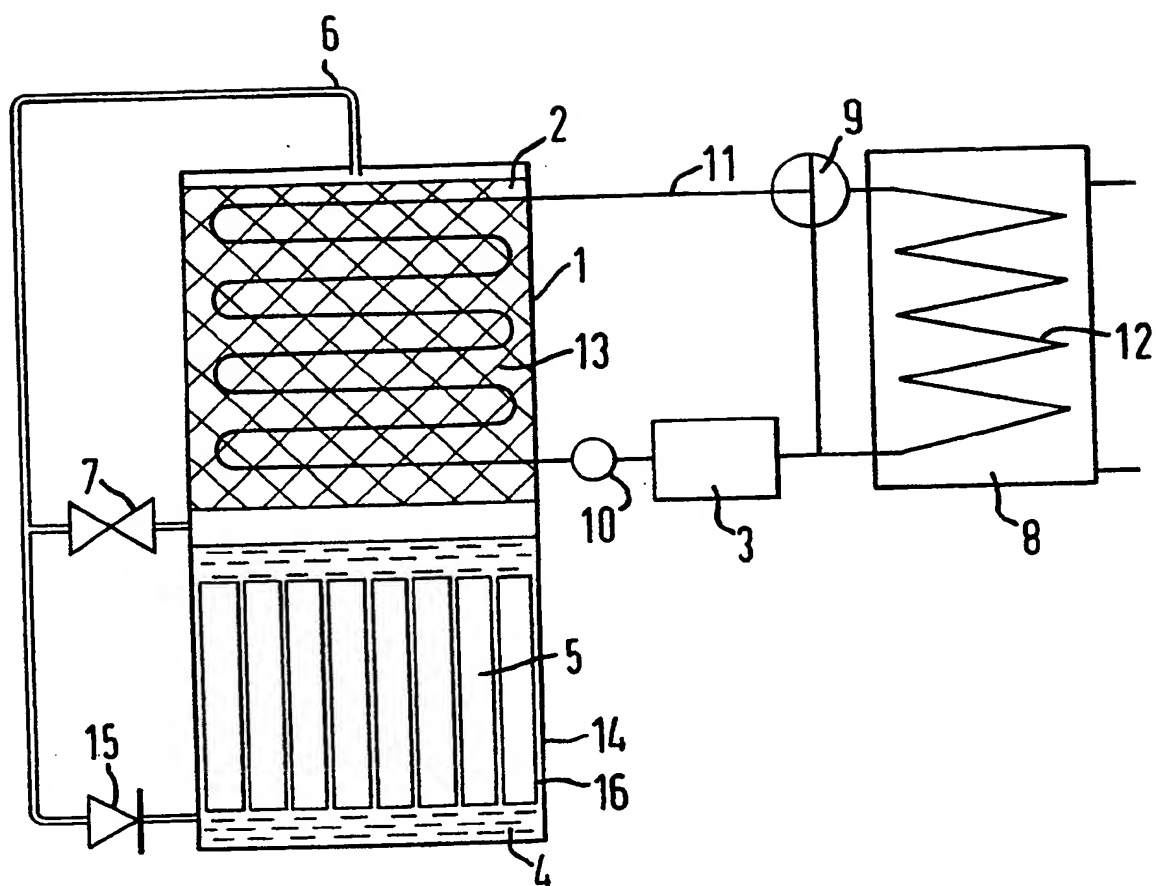
pump 10, the circuit containing a heat source 3 (e.g. using off-peak electricity) capable of supplying heat to a first heat exchanger 2 and to the load, (e.g. a calorifier heat exchanger 12 or domestic radiators); a first compartment 1 containing an adsorbent 13 (e.g. a zeolite molecular sieve) capable of exchanging heat with the said heat exchanger 2; a second compartment 14 containing in one or more liquid-tight receptacles 16 a substance with a relatively low melting point and a relatively high heat of fusion (e.g. sodium sulphate decahydrate); a valved conduit 6 interconnecting said compartments; and an adsorbate (e.g. water, hydrogen iodide methanol or ammonia) in said compartments. To store heat in receptacles 16, valve 9 is set so that said fluid, heated by the source 3 by-passes the load heat exchangers (e.g. 12), the latter being (via valve 9) reintroduced into the circuit when heat is required for the load.



GB 2 081 875 A

The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

1/1



## SPECIFICATION

## Heat storage system

5 This invention relates to a heat storage system in which heat is stored partly as heat of adsorption and partly as heat of fusion. 5

At present the operating costs of off-peak electricity and oil fired domestic heating systems are roughly the same. However it is likely that in future oil prices will rise at a faster rate than electricity as more nuclear plant is introduced. Furthermore, since the fuel costs of nuclear power are low compared with the cost of investment the economics of nuclear power are very sensitive to load factor and there will be strong incentive for utilities to attempt to flatten the diurnal load profile and hence the policy of providing cheap off-peak power is likely to continue. 10

Current off-peak heating systems are not compatible with the piped water system used with fossil fuel firing and hence the cost of converting from oil to off-peak electricity is at present considerable. It would be an advantage therefore if a system could be devised whereby the piped water system including radiators could be retained and coupled to a central off-peak energy storage system. We have now devised such a storage system and in accordance with this invention a heat storage system comprises a continuous pipework in which fluid can circulate having a circulation pump for the fluid, a source of heat capable of supplying heat directly or indirectly to a first heat exchanger and to the load. This first heat exchanger is capable of exchanging heat with adsorbent housed in a first container. Also there is a second container housing a substance with a relatively low melting point and a relatively high heat of fusion, said substance being housed in one or more separate liquid-tight receptacles. This second container is connected by a valved conduit to the first container housing the adsorbent. 15 20

The great advantage of the heat storage system of the invention is that heat is stored at relatively low temperatures and hence the heat losses are minimal compared with systems storing heat at higher temperatures. 25

The continuous pipework can house any fluid but generally it will be water or a liquid having a boiling point of at least 100°C, e.g. silicone oil, which circulates in the pipework. In order that heat can be supplied to the fluid in the pipework, the pipework will be connected to a source of heat. The source of heat envisaged is primarily off-peak electricity used directly via a resistance heater. However in some cases it could be possible to utilise it indirectly via a heat pump. 30

This source of heat must be capable of supplying heat separately or simultaneously to the load and a first heat exchanger. The load will be the heating system of the building concerned and this will usually be a series of radiators located in the rooms of the building. If water is used as the fluid in the pipework the pipework can conveniently be extended to communicate with all the radiators via a conventional water circuit. However, heat can be supplied indirectly to the load, by means of one or more heat exchangers for example calorifiers, and this will be desirable when the fluid is non-aqueous. 35

Also located in the continuous pipework is a circulation pump capable of circulating fluid throughout the pipework. This may for example be an electrical pump. 40

Although not essential, it is highly desirable if the pipework is provided with a valve which can actuate or close the supply of heat to the load. In this manner fluid can be made to flow either to the load or to the first heat exchanger or to both. 45

The pipework is also provided with a first heat exchanger and this is designed to exchange heat with adsorbent housed in a first container. Suitable adsorbents include zeolite molecular sieves and activated charcoal. 50

The heat storage system also contains a second container housing in one or more liquid-tight receptacles, for example plastic bags, a substance with a relatively low melting point i.e. below 40°C and a relatively high heat of fusion, i.e. above 200 kJ/kg. Such substances are preferably hydrated salts. The preferred example of a hydrated salt is sodium sulphate decahydrate with a m.p. of 32°C and a heat of fusion of 251 kJ/kg. Other examples are calcium chloride hexahydrate (m.p. 29°C), disodium hydrogen phosphate dodecahydrate (m.p. 35.5°C) and zinc nitrate hexahydrate (m.p. 35°C). 55

It may sometimes be necessary for the hydrated salt to have been treated so as to prevent phase separation. One such method of treatment is described in European patent publication 0000099.

The first container is conveniently located above the second container i.e. both containers may be formed from one vessel divided by a horizontal partition. However this arrangement is not essential. 60

The first and second containers are connected together by a conduit having a valve therein so that fluid connexion between the two containers can be controlled.

Also present in one or both containers is an adsorbate, and this is preferably water, although it may for example be hydrogen iodide, methanol or ammonia. Suitable adsorbent/adsorbate systems are zeolite/ water and activated charcoal/hydrogen iodide. 65

The adsorbate transfers between the two containers via the valved conduit in accordance with the processes of the invention hereinafter described. It is also highly desirable that there is also a second valve in this conduit, this second valve being non-return. The purpose of this is to ensure that adsorbate vapour from the first container is condensed by contact with adsorbate which has already condensed when it enters the second container. Thus, this second non-return valve should be located in a portion of the conduit which

enters the bottom portion of the second container and the other valve can be on a portion of the conduit entering the top portion of the second container.

In order to store heat using the heat storage system of the invention the source of heat is used to supply heat to the fluid in the pipework and the circulation pump operated. Whilst this heating occurs if the pipework has a valve it will be possible to heat simultaneously the building and first heat exchanger with off-peak power or else restrict the supply of heat to the first heat exchanger only. Of course if simultaneous heating is required it must be arranged that the circulation pump sends the heated fluid to the first heat exchanger before being sent to the load. The heated fluid causes the first container and hence the adsorbent and any adsorbate present to be heated. The adsorbate is evaporated from this first container and passes via the valved conduit to the second container where it condenses and melts the substance with the low melting point and high heat of fusion housed in one or more liquid tight receptacles. Heat is therefore stored in this first container as potential heat of adsorption and in the second container as latent heat of fusion. When a second non-return valve is present in the system the evaporated adsorbate passes through this valve to the second container.

In order to obtain heat from the storage system with the valve in the valved conduit open, fluid is circulated in the pipework by means of the circulation pump and through the first heat exchanger and this cools the adsorbent. At the same time adsorbate is evaporated from the second container and passes through the valved conduit to the first container and is re-adsorbed by the adsorbent with the release of heat. This heat raises the temperature of the fluid in the pipework and hence supplies heat to the load and hence to the radiators etc., in the building. If however the valve in the valved conduit is closed this cannot occur and effectively the heat is cut off. Hence this valve can be used to regulate the release of the stored energy and may be opened or closed so as to maintain the fluid temperature in the pipework and hence via the load, in the radiators etc at a set temperature.

It is highly desirable that the adsorbent/adsorbate system has a high heat of adsorption and this is preferably substantially greater, eg at least 1.5 times, than the latent heat of evaporation of the adsorbate. As an example 13x zeolite molecular sieve (adsorbent) adsorbs 0.3 kg H<sub>2</sub>O/kg at an average heat of adsorption of 79.4 KJ/mol H<sub>2</sub>O. This gives an energy density of  $823 \times 10^3$  KJ/m<sup>3</sup> so that a cubic metre of adsorbent will store 228 K.w.h. When the zeolite is dried out by the use of off peak power the latent heat of condensation of displaced water is stored by being used to melt the substance with a low melting point and high heat of fusion which for the purpose of this example is Na<sub>2</sub>SO<sub>4</sub>·10H<sub>2</sub>O, at about 32°C. This salt will store energy at a density of  $552 \times 10^3$  KJ/m<sup>3</sup> but the amount which must be stored in this manner will only be 44.6/79.4 times that delivered to the adsorbent. The size of the hydrated salt energy store in relation to the size of the adsorbent will therefore be

$$\frac{823}{522} \times \frac{44.6}{79.4} = 0.84$$

No storage capacity will be required during the hours when for example off-peak electricity is available and if for example this availability is for six hours/day and the mean heating load is 20,000 KJ/hour or approx. 5.5 Kw then the volume of the heat store is about 0.9 m<sup>3</sup> which is not too large.

A heat storage system according to the invention is now described with reference to the drawing.

The pipework 11 contains silicone oil as circulating fluid and has a heat exchanger 2, electrical circulating pump 10, electrical heater 3, heat exchanger 12 and three-way valve 9. Heat exchanger 12 heats a calorifier 8. 13x zeolite molecular sieve 13 is housed in compartment 1 and this compartment is connected via conduit 6 and valve 7 and non-return valve 15 to compartment 14 which houses sodium sulphate decahydrate 5 and water (adsorbate) 4.

To store heat in the system valve 9 is set so that the silicone oil in the pipework does not pass through calorifier 8 but merely circulates by means of pump 10 through the heat exchanger 2. Heat is supplied to the silicone oil to raise the temperature to 100°C or more by means of the heater 3 and this heat causes water vapour to be driven off from the zeolite molecular sieve 13 in the compartment 1. This water vapour passes via conduit 6 and non-return valve 15 to the compartment 14 where it condenses, and the heat of condensation melts the sodium sulphate decahydrate housed in the bags 16 at about 32°C. When heat is required from the system, the valve 9 is altered so that hot silicone oil can pass through heat exchanger 12. The relatively cold silicone oil in pipework 11 is circulated by means of pump 10, and with valve 7 open, water 4 is evaporated from compartment 14 passing via conduit 6 to compartment 1 where it is re-adsorbed by zeolite 13 releasing heat, thereby heating the circulating silicone oil in pipework 11 and hence calorifier 8. By opening or closing valve 7 one can control the amount of water evaporated from compartment 14, thereby controlling the temperature of the circulating silicone oil in pipework 11.

Instead of using silicone oil as the circulating fluid one can use water in cases where the desorption temperature is below 100°C. In this case there will be no calorifier 8 and the pipework is merely connected to the radiators in the building by conventional water circuitry. The operation of the device will be same in all other respects.

## CLAIMS

1. A heat storage system comprising a continuous pipework in which fluid can circulate, said pipework having a circulation pump for the fluid, a source of heat capable of supplying heat directly or indirectly to a first heat exchanger and to the load; a first container housing adsorbent capable of exchanging heat with said first heat exchanger; a second container housing in one or more separate liquid-tight receptacles a substance with a relatively low melting point and a relatively high heat of fusion; a valved conduit connecting said first container to said second container; and adsorbate in one or both containers. 5
2. A system according to claim 1 wherein the source of heat is off-peak electricity.
3. A system according to either of claims 1 and 2 wherein the adsorbent is a zeolite molecular sieve. 10
4. A system according to claim 3 wherein the adsorbate is water.
5. A system according to any one of the preceding claims wherein the substance with a relatively low melting point and a relatively high heat of fusion is a hydrated salt.
6. A system according to claim 5 wherein the salt is sodium sulphate decahydrate.
7. A system according to any one of the preceding claims wherein the adsorbent/adsorbate system has a heat of adsorption at least 1.5 times the latent heat of evaporation of the adsorbate. 15
8. A system according to any one of the preceding claims wherein the pipework has a valve which can control the flow of fluid to the load.
9. A system according to any one of the preceding claims which includes a second non-return valve in the conduit connecting the two containers. 20
10. A process of storing heat using the heat storage system according to any one of claims 1 to 8 which comprises supplying heat to the fluid in the pipework whilst the circulation pump is operating, thereby causing the first container to be heated so that adsorbate present therein is evaporated and passes through the valved conduit to the second container where it condenses and melts the substance with a low melting point and high heat of fusion. 25
11. A process according to claim 10 wherein the system is in accordance with claim 8 and the valve in the pipework prevents fluid flow to the load.
12. A process according to either of claims 10 and 11 wherein the system is in accordance with claim 9 and adsorbate vapour passes through the second non-return valve to the second container where it is condensed. 30
13. A process of obtaining heat from the storage system according to any one of claims 1 to 9 wherein with the valve in the valved conduit open, fluid is circulated in the pipework by means of the circulation pump and supplies heat to the load.
14. A heat storage system according to claim 1 substantially as hereinbefore described with reference to the drawing. 35